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The activity of Lumbricidae, Acarina and Collembola in the straw humification process

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With 6 Figures

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1. Introduction

With every year the effect of the soil fauna on the humification process is more widely acknowledged. Quite a lot of studies are dedicated to elucidate the importance of the soil fauna in the humification of organic substance in forests (e.g. Dunger, 1958; Zachariae, 1962; Perel, Sokolov, 1964) and in the humification of compost (Chernova, 1966). It is very important that organic humification of substances in fields under cultivation should proceed rapidly. Many researchers are interested in the humification of straw. The effect of Lumbricidae on the humification of straw in hothouses was investigated by Heitor, Soares Ribeiro 1963. The effect of Collembola on the humification of rye straw was examined by Naglitsch and Grabert 1968.

Soil organisms are conditioned not only by the properties of the soil but also by their own mutual biocoenotic relations (e.g. Törne, 1963, 1964). In trying to assess the effect of soil fauna on the humification process it is important to examine under what conditions this or that influence occurs and what are the exact biocoenotic interrelations existing among various groups of organisms (Ghilarov, 1968).

This aim of our work was to evaluate the activity of Lumbricidae, Acarina and Collembola and the dynamics of their densities and also their mutual biocoenotic relations in the process of humification of straw occurring in various soils.

2. Methods

We investigated the activity of Lumbricidae, Acarina and Collembola in the process of the humification of straw and their mutual relations and densities in various soils. For this purpose we made parallel studies in vegetative pots in 1965—1968. To each vegetative pot 2.5—4.5 kg of sieved soil and 60 g of straw (17 t/ha) were added. Straw was chaffed (3—5 cm in length), moistened with water and put in the gauze bags. In autumn they were put nearer to the surface, in spring nearer to the bottom (fig. 1, a, b). In 1966—1967 we used barley straw and in 1967—1968 rye straw.

All the series had 2—4 replications and 4—5 variants with the different numbers of Lumbricidae (*Allolobophora caliginosa* f. *typica* Sav.): (1) control (no Lumbricidae), (2) 4 Lumbricidae, (3) 8 Lumbricidae, (4) 16 Lumbricidae, (5) 24 Lumbricidae.

The numbers of Lumbricidae (4, 8, 16, 24) put in the vegetative pots corresponded to the following densities in 1 sq.m: 4 to 115; 8 to 230; 16 to 460 and 24 to 690. 115 or 230 specimens of Lumbricidae to 1 sq.m of soil represent on the average normal densities of earthworms in the soils investigated but 460 and 690 specimens of earthworms to 1 sq.m (corresponding to our numbers 16 and 24 respectively) are 2—3 times higher than the

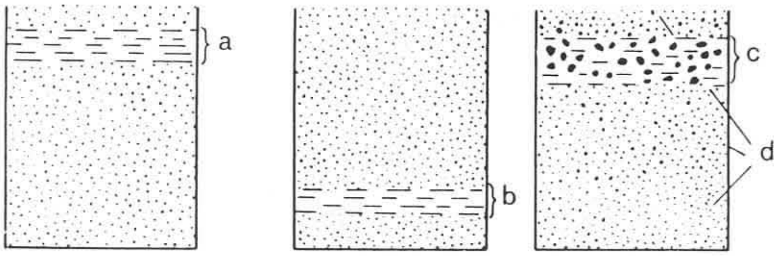


Figure 1. Scheme of adding straw to the vegetative pots and removing samples from them:
a — in autumn at the beginning of the experiment the straw was inserted in the vegetative pots 3—5 cm below the soil surface;
b — in spring the straw was put 3—5 cm above the bottom;
c — the straw and worm casts layer from which Acarina and Collembola were separated;
d — the soil (0.25 l) from which Acarina and Collembola were also separated.

normal earthworm densities found in the soils. The numbers of Acarina and Collembola in our experimental soils remained unchanged, that is their numbers were those normally found in our investigated soils. In summer (May—September) vegetative pots were kept in the open air and barley was cultivated in them; in winter (October—April) the pots were kept in a hothouse, the temperature being 10—16 °C. The samples for investigation were taken twice: (1) 6 months and (2) 10—14 months following the start of experiments. Acarina and Collembola were separated by the modified Tullgren technique out of the straw-worm casts layer and out of the soil which was mixed after the removal of the straw layer; the sample of 0.25 l of soil was taken from each variant (fig. 1, c, d). When Acarina and Collembola were separated from the straw-worm casts layer the next element to be separated was coprolites; this was done by sieving or washing. After that both dry worm casts and dry straw were weighed separately. The straw that remained undecayed was again put in the same vegetative pots. When, on checking, we found the numbers of *A. caliginosa* diminished, they were supplemented up to the original number (4, 8, 16 or 24). The samples of soil were taken from such sites where competent soil specialists had previously investigated their properties. The corresponding data regarding the properties of the soli are presented in table 1.

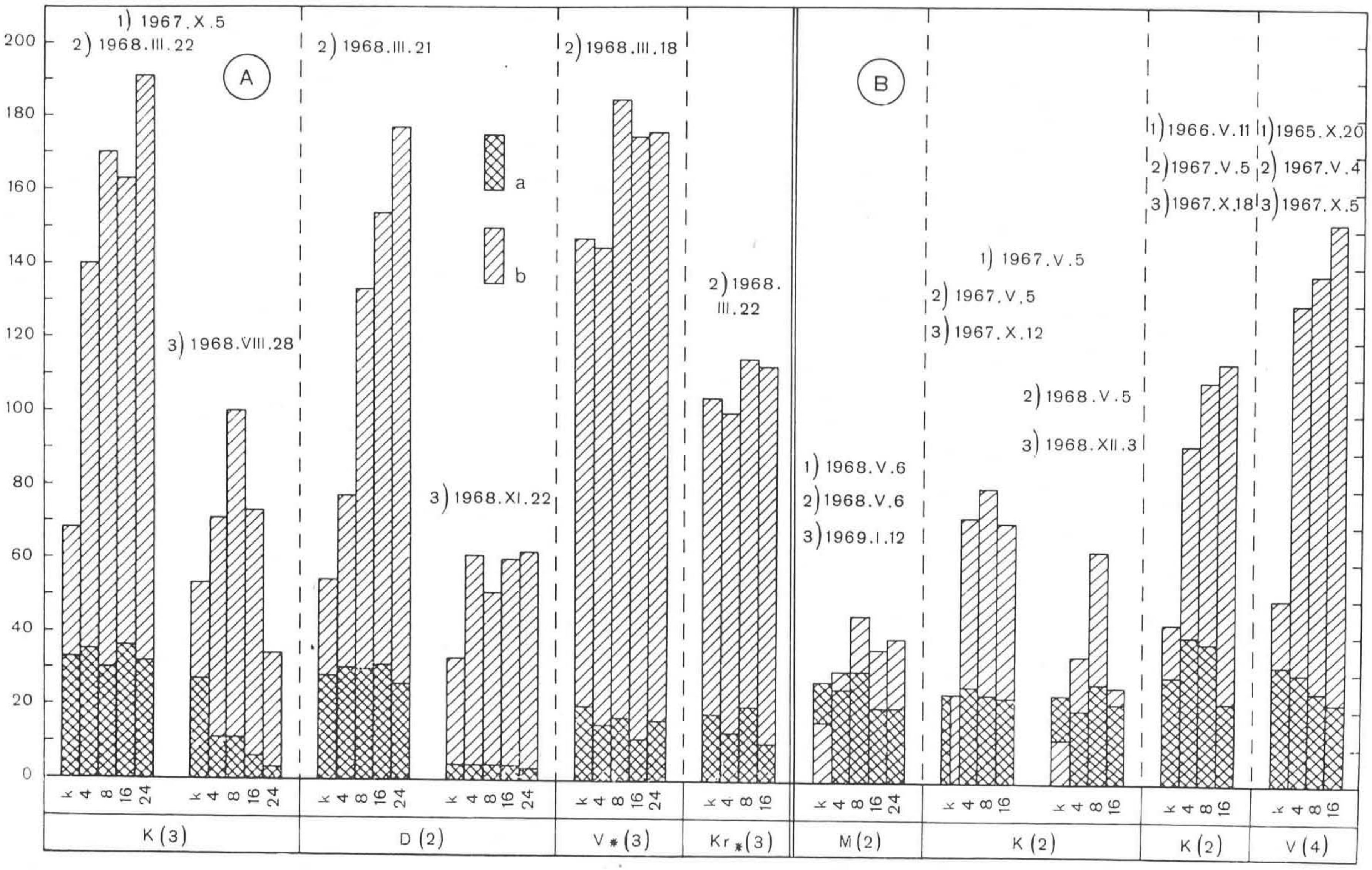
Table 1 Soil properties

Number	Soil type	Abbreviated name of the soil	pH	Humus percentage
	Soddy podzolic			
1	sandy loam	V	5.3	2.4
2	sandy clay loam	D	5.1	1.3
3	sandy clay loam	M	4.3	1.6
	Soddy gley			
4	sandy clay loam	K	6.9	7.2
5	sandy clay loam	Kr	7.3	3.0

3. Results

3.1 The activity of Lumbricidae (*Allolobophora caliginosa f. typica* Sav.) in the process of humification of straw.

The active role of Lumbricidae in the process of humification of straw can be evaluated according to the amount of worm casts added to the straw layer. The amount of worm casts in the straw is directly proportional to the numbers of Lumbricidae. The worm casts were more abundant in the variants where there was a higher number of


200
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140
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A
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1) 1967.X.5
2) 1968.III.22
3) 1968.VIII.28
2) 1968.III.21
3) 1968.XI.22
2) 1968.III.18
2) 1968.III.22
1) 1968.V.6
2) 1968.V.6
3) 1969.I.12
1) 1967.V.5
2) 1967.V.5
3) 1967.X.12
2) 1968.V.5
3) 1968.XII.3
1) 1966.V.11
2) 1967.V.5
3) 1967.X.18
1) 1965.X.20
2) 1967.V.4
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k 4 8 16 24
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k 4 8 16
K (3)
D (2)
V* (3)
Kr* (3)
M (2)
K (2)
K (2)
V (4)

Fig. 2

Lumbricidae (8, 16, 24). In these variants the weight of worm casts that were produced by Lumbricidae amounted to 140—190 g. In all the experimental variants where there were Lumbricidae the amount of worm casts was 2—3 times higher than the amount of soil that penetrated into straw in the control variants.

The influence of Lumbricidae on the intensification of humification of straw (i.e., on the decrease of straw weight) following 6 months after the start of the experiment is hardly noticeable. With slight fluctuations the weight of straw has by this time decreased up to 50 per cent in all the variants while in some types of soil (V, Kr) the figure was even higher (65—70 per cent) (fig. 2, A, B). After checking our vegetative pots 10 months following the start of the experiment the influence of Lumbricidae on the straw humification intenseness was clearly established (in the soils V, K; fig. 2, A, B). In checking our samples later on, 11—14 months after the initial stage of the experiment, some types of soil (V, Kr) had their straw decayed in all the variants and therefore we could not have noticed the influence of Lumbricidae on the intensification of humification of straw; this was especially the case because the influence of Lumbricidae on humification of straw was more marked at the end of that process. It is of no importance for the bulk of worm casts whether straw is added to the soil at the beginning of the experiment or 1 or 2 years following the activity of Lumbricidae in the soil; also of no importance for the bulk of worm casts is the question whether or not the soil is fertilized by the straw for the second time. The bulk of worm casts is slightly increased when the straw is nearer to the soil surface (in autumn) than it is at the bottom of the pots (in summer: see fig. 2, A, B). Soil properties are the main factor that influences the bulk of worm casts; the latter is conditioned by the unequal specific weight of soil. It is to be assumed that the survival of Lumbricidae in the vegetative pots also has its own influence on the bulk of worm casts found there. The survival of Lumbricidae depends both on the properties of the soil and on the number of Lumbricidae present. The earthworms survive much better in those types of soil which contain more humus and are less acid. Lumbricidae survive better in those cases when their densities in the vegetative pots are lower (4 or 8 specimens) than higher (16 or 24 specimens; see fig. 3). Soil fertilization by straw has a positive effect on the survival of Lumbricidae (ATLAVINYTĖ, BAGDONAAIČIENĖ, 1968).

3.2. The densities of Acarina in the process of humification of straw

During the period of humification of straw the numbers of Acarina increase up to tens of times in comparison with the soil which is not fertilized. Higher numbers of Acarina accumulate in the straw and the layer of Lumbricidae worm casts (40—150 specimens) than in the soil itself. In the soil of the vegetative pots the numbers of Acarina are 3—6 times lower (10—50 specimens) than they are in the straw layer (fig. 4, A, B). The densities of Acarina are higher in the middle of humification process (6 months following the start of the experiment) and considerably lower (or even they vanish alto-

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Figure 2. *A. caliginosa* casts accumulation and dynamics of humification of straw:

A — experiments begun in autumn; a — straw; b — worm casts. 1) The date of the beginning of the experiment; 2), 3) The date of sampling; K, D, V — the types of soil; k, 4, 8, 16, 24 — the variants of the experiment; (2), (3) The number of experimental replications; * — the types of soil where the straw decayed totally after 12 months.

B — experiments begun at various time;

1 — the date of the beginning of the experiment; 2 — the date of straw insertion; 3 — the date of sampling.

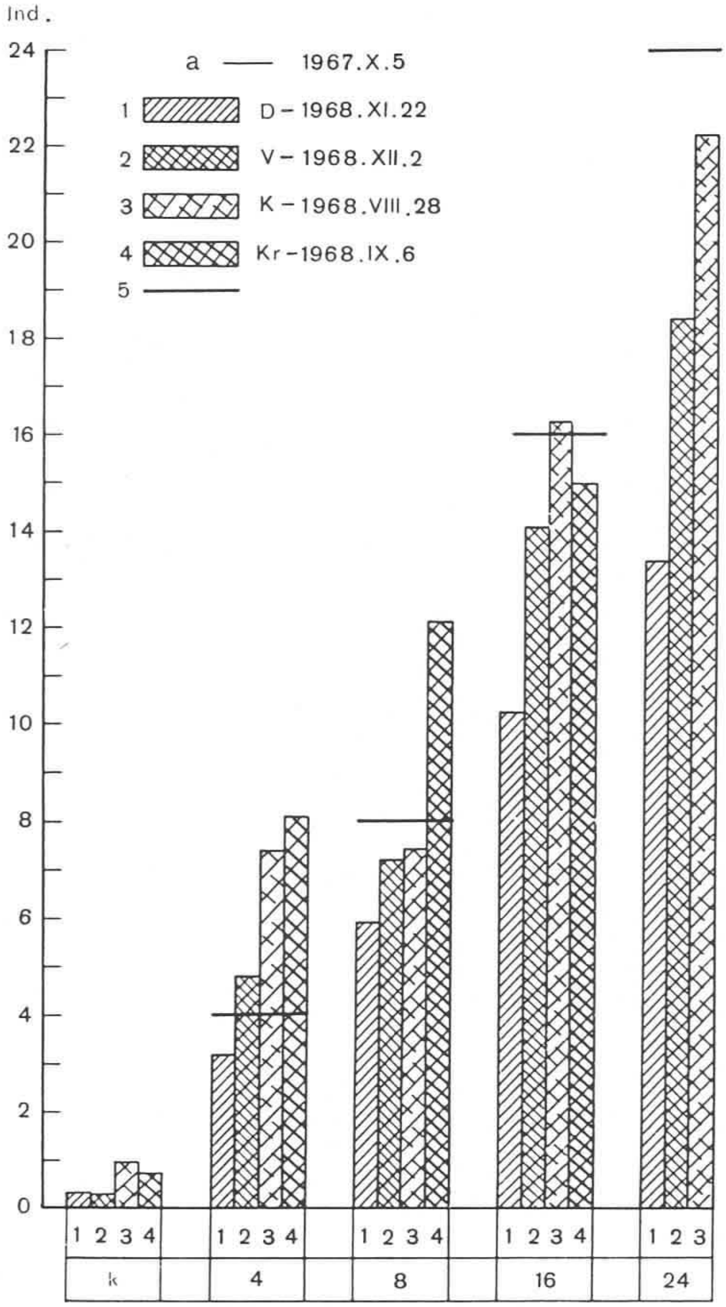


Figure 3. The survival of *Allolobophora caliginosa* in the vegetative pots containing various types of soil:
a — the date of the beginning of the experiment; 1—4 — the types of soil and the date of the end of the experiments; 5 — the limit of the number of *A. caliginosa* at the beginning of the experiment; k, 4, 8, 16, 24 — the variants of the experiment.

gether) both in the straw and the soil at the end of straw humification process (10—14 months after the beginning of the experiment).

As one can see from fig. 4 (A, B) the numbers of Acarina fluctuated considerably in the straw layer of all the variants and in relation to the numbers of Lumbricidae they did not behave in any regular manner, except in some of the control variants where the numbers of Acarina were lower than in the experimental variants.

In the soil layer, however the numbers of Acarina were proportionate to those of Lumbricidae. In the middle of humification process of straw (6 months after the start of the experiment) the numbers of Acarina in our experimental variant increased proportionally to the

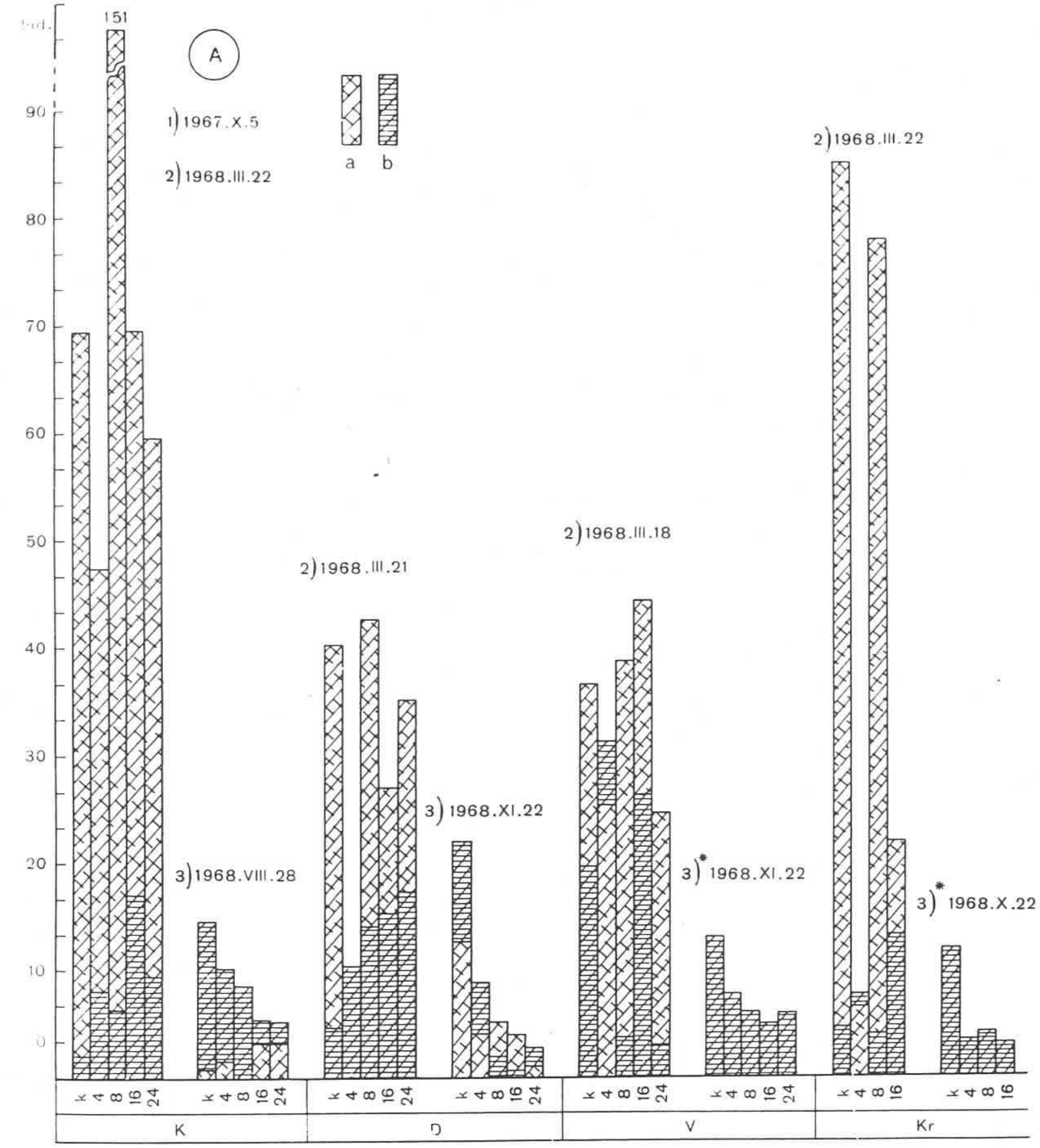
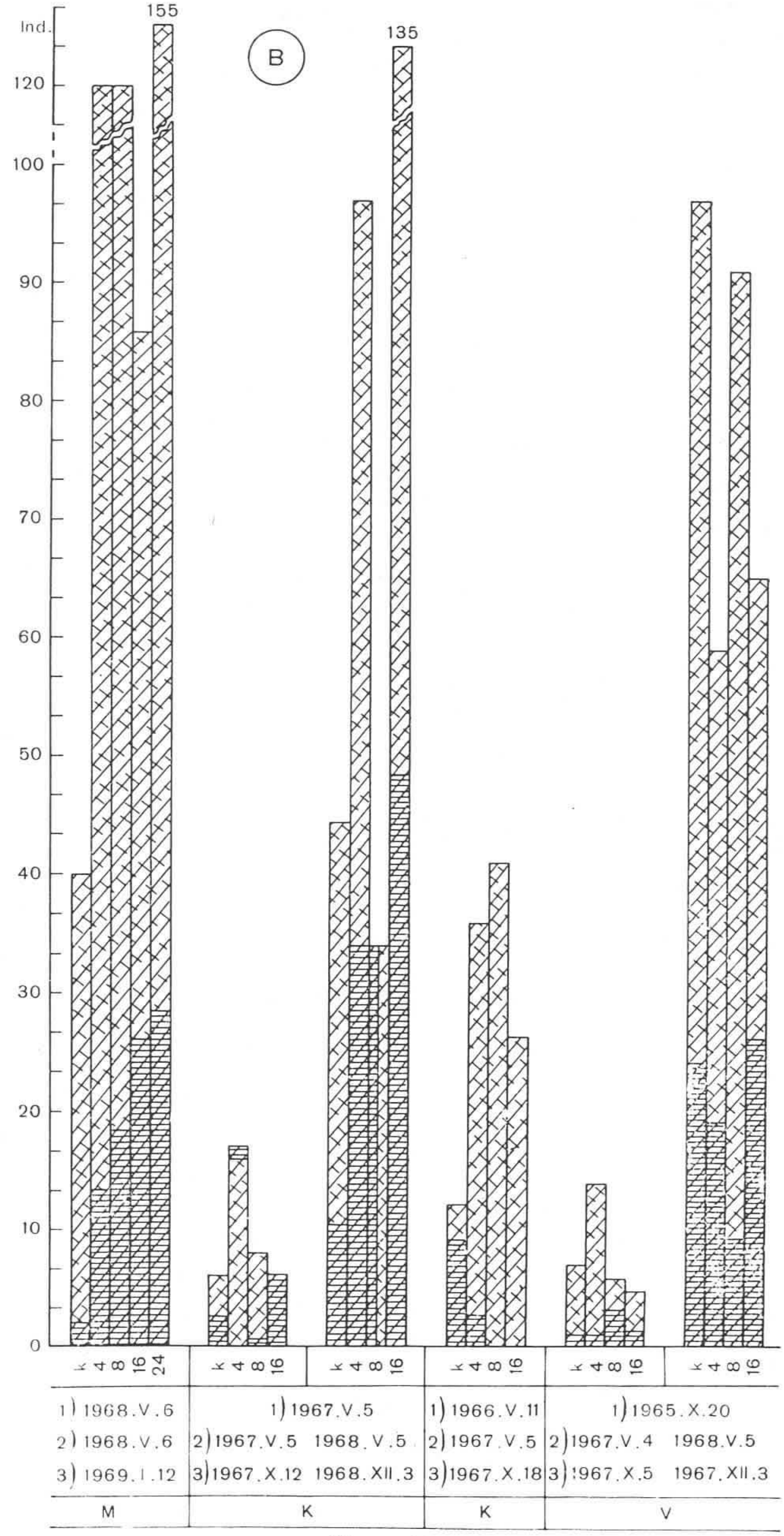


Figure 4 A. The densities of Acarina in the soils fertilized by straw:
A — experiments begun in autumn; a — the Acarina in the straw-worm casts layer; b — Acarina in the soil; 1 — the date of the beginning of the experiment; 2, 3 — the dates of Acarina checking.

increasing numbers of Lumbricidae (4, 8, 16, 24) while at the end of the humification process the numbers of Acarina in the soil were inversely proportional to the increasing numbers of Lumbricidae (fig. 4, A and B). Such proportional increase or decrease of the numbers of Acarina according to the numbers of Lumbricidae in the experimental soil indicates a mutual relationship between Acarina and Lumbricidae in some of the periods of the humification process. Neither the soil properties nor the period of fertilization by straw (in autumn or in spring) had any noticeable effect on the increase in the numbers of Acarina.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1) 1968.V.6
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3) 1969.I.12
1) 1967.V.5
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3) 1967.X.12 1968.XII.3
1) 1966.V.11
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3) 1967.X.18
1) 1965.X.20
2) 1967.V.4 1968.V.5
3) 1967.X.5 1967.XII.3
M
K
K
V

Figure 4 B.

3.3. Collembola densities and their dynamics in the process of humification of straw

During the straw humification process the densities both of Collembola and Acarina increase considerably. In the soil not fertilized by straw (the same variants of the experiment) the densities both of Collembola and Acarina are slight and we can find only isolated specimens (table 2).

Table 2 The densities of Acarina and Collembola in the soil unfertilized by straw (in the vegetative pots)

Soil type and the beginning of the experiment	Checking time	Experiment replication number	Variants and the numbers of Lumbricidae									
			k Acarina	4	8	16	24	k Collembola	4	8	16	24
K 1965.10.25	1967. 4.26	2	24.0	2.0	1.0	2.0	n	13.0	0.5	0.5	6.5	n
D 1967.10.5	1968. 3.21	2	2.0	2.3	—	0.6	1.6	—	3.3	—	3.0	0.3
D 1967.10.5	1968.12.13	2	0.3	—	—	0.6	—	1.0	—	0.3	1.6	0.6

n — not investigated

The number of Collembola increases in the straw-worm casts layer up to several hundreds or several thousands of specimens. In the straw layer Collembola are 2—10 times more abundant than the corresponding number of Acarina. In the soil of vegetative pots the number of Collembola amounts only to several tens of specimens. At the end of humification of straw the number of Collembola diminishes both in the straw and in the soil (fig. 5). The number of Collembola increases more when soil is fertilized by straw in spring than in autumn (fig. 5, B). The number of Collembola in separate variants of the experiment fluctuated in an irregular way and we could not detect any biocoenotic relationship with Lumbricidae. On the other hand, while analyzing the densities of Collembola according to their different species, we have noticed the influence which the number of Lumbricidae had on Collembola. In our present investigations 24 different species of Collembola were determined.1) Most numerous in specimens were the following species of Collembola: *Hypogastrura succinea* GISIN, *Folsomia quadrioculata* TULLBERG, *F. fimataria* (LINNÉ), *Proisotoma minuta* TULLBERG, *Isotoma notabilis* SCHÄFFER, *I. viridis* BOURLET. In the straw humification process these species of Collembola were not equally abundant. In the middle of humification of straw (6 months after the beginning) the following species were most numerous: *H. succinea*, *F. quadrioculata*. At the end of humification *F. fimetaria* was more numerous. These Collembola were more numerous after 6 months in the variants which had more numerous Lumbricidae (16, 24) too.

Thus we may suppose that separate species of Collembola take different part in the humification process, some species being more active at the beginning of the process, others in the middle, others still at the end of the process. The diminution or the increase in separate species of Collembola as well as Acarina in the compost humification process was noticed by CHERNOVA (1966).

In order to ascertain the activity of separate species of Collembola at separate stages of humification process of straw in a more precise manner a detailed analysis of Collembola is needed.

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1) The species of Collembola were determined by I. SUKACKIENĖ, the scientific collaborator of the Institute of Zoology and Parasitology.

Figure B — experiments begun at various times; 1 — the date of the beginning of the experiment; 2 — straw insertion date; 3 — the date of Acarina checking; other explanatory notes in Fig. 2.

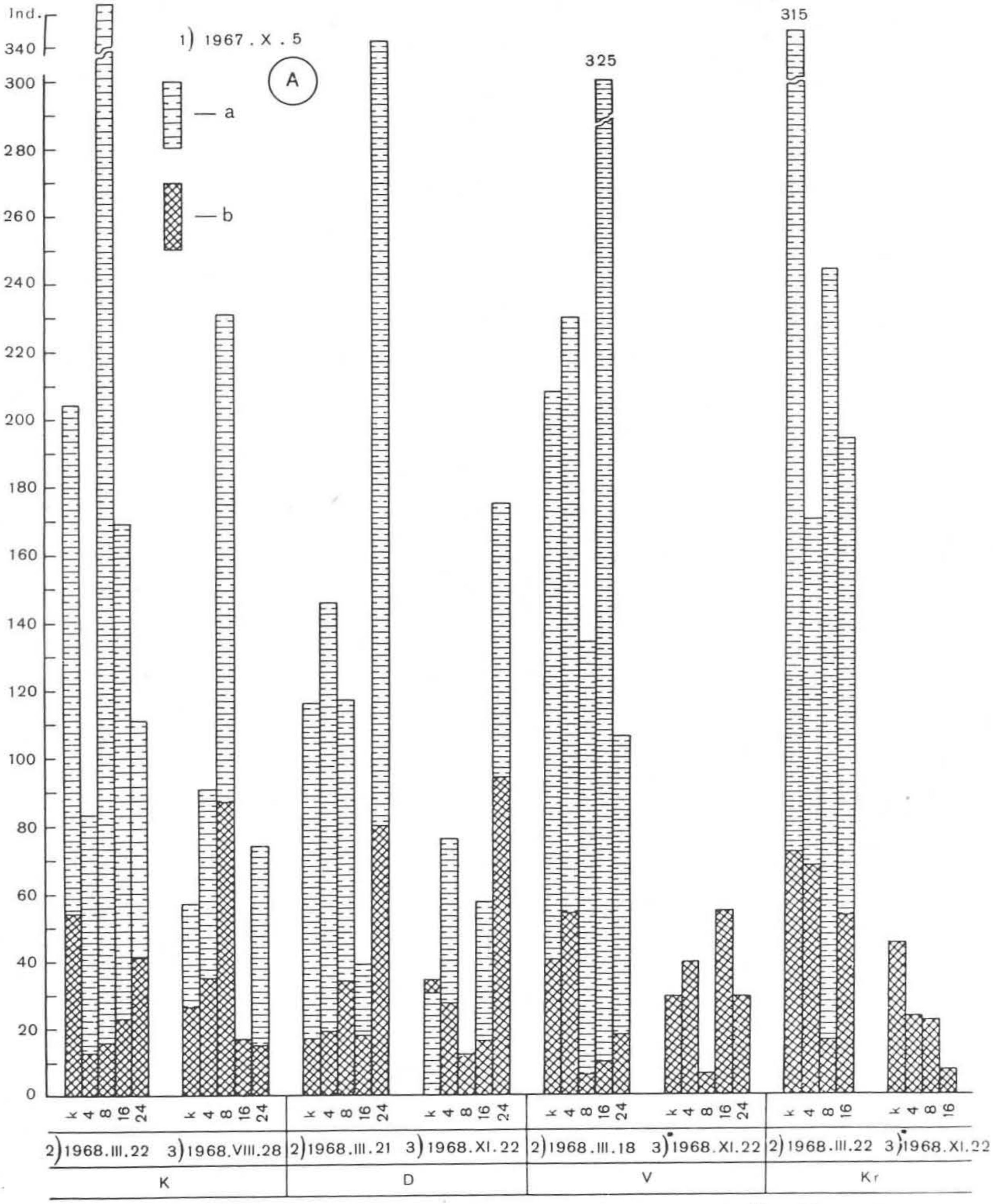
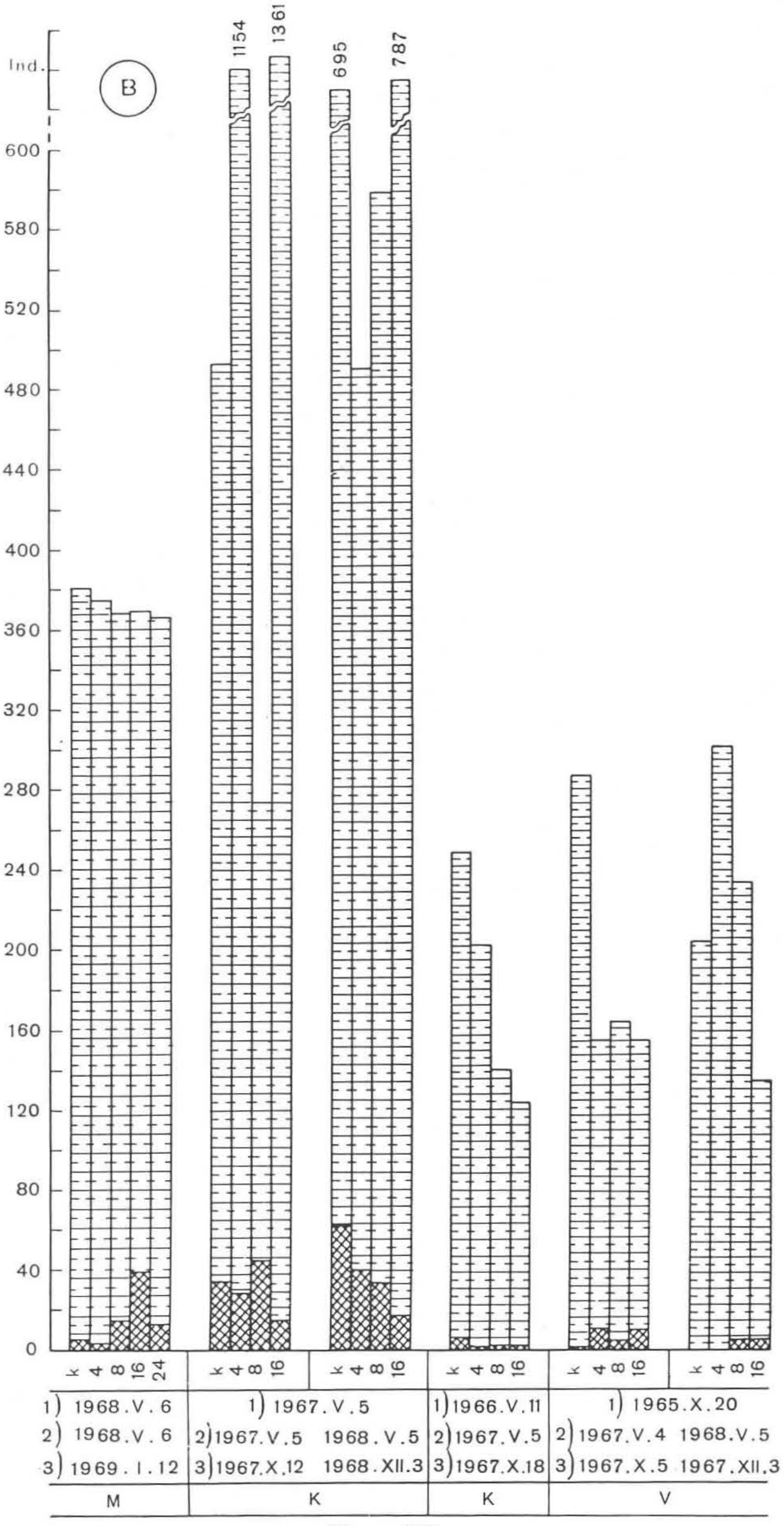


Figure 5. The densities of Collembola and their dynamics in the soils fertilized by straw: a — the number of Collembola in the straw-worm casts layer; b — the number of Collembola in the soil; A — experiments begun in autumn; B — experiments begun at various times; other explanatory notes in Fig. 4.

3.4. The effect of Lumbricidae on the barley crop in the soils fertilized by straw

The effect of Lumbricidae on the soil properties is seen from the increase in barley crops (240—280 per cent) in relation to the numbers of Lumbricidae (fig. 6). The effect of Lumbricidae on the barley crop is also positive in the soils not fertilized by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M
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Figure 5 B.

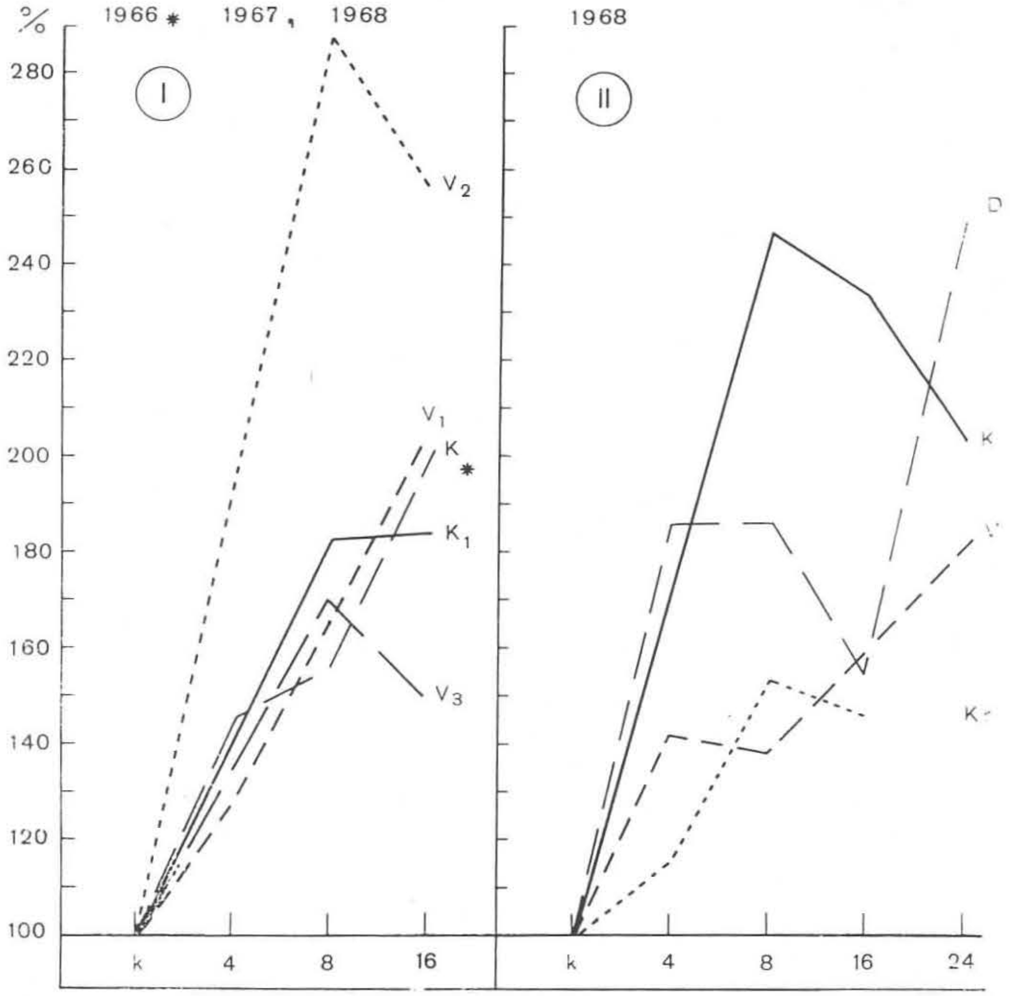

Figure 6. The effect of *Allolobophora caliginosa* on the barley grain crops:

I — barley crops obtained in soils fertilized by straw in different periods of 1966, 1967, 1968; V_1 — fertilized for the first time in autumn; V_2 — fertilized for the second time in spring; V_3 — fertilized for the third time in spring; K_1 — fertilized for the first time in spring; K —not fertilized.

II — barley grain crops in 1968; the experiments begun and the soil fertilized by straw in autumn (1967. 10. 5.).

straw (Atlavinytė, Bagdonavičienė, Budavičienė, 1968) that is in such experiments where the numbers of Acarina and Collembola were slight. Thus the role of Acarina and Collembola becomes more apparent in the straw humification process while the corresponding number of Lumbricidae has its effect also on the other soil properties which in their turn increase crops of different cultures.

4. Conclusions

Lumbricidae (*Allolobophora caliginosa* f. *typica* Sav.), Acarina and Collembola show activity in the humification process of straw. *A. caliginosa* deposits worm casts in the straw layer and by doing so increases the process of humification of straw. The numbers of Acarina and Collembola increase during straw humification process up to several tens of times in comparison with the corresponding numbers seen in the soils unfertilized by straw. The specimens of Acarina and more Collembola are numerous in the straw layer than in the soil without the straw.

At certain stages of the straw humification process biocoenotic relationship between Lumbricidae, Acarina and Collembola become evident. In the middle of humification process the number of Acarina in the soil is proportional to the number of *A. caliginosa* and at the end of humification process their number decreases with the increase in the numbers of *A. caliginosa*. Those species of Collembola (*Folsomia fimetaria* Linné) which were more numerous at the end of the humification process become more abundant in the places where there was a larger number of *A. caliginosa*.

A positive effect of *A. caliginosa* on the humification of straw and other soil properties is evident by the increased crops which are proportional to the number of *A. caliginosa*.

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